Computational Analysis of Steel Joists at Elevated Temperatures

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Computational Analysis of Steel Joists at Elevated Temperatures

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Faculty Mentor: Dr. Jean Batista Abreu, Assistant Professor of Engineering
Steel Joists

- Joist - horizontal structural member typically used to support a floor or ceiling
- Type - Lipped Channel Section Joists (C-Section Joists)
- Modeling Program - Abaqus
Currently: Steel joist are tested experimentally by subjecting them to standard time-temperature fire curves

Limitations:

- Tests are expensive
- Limited number of joist configurations
- Barely represent loading and support conditions of steel joists in a building
- Impossible to estimate the performance produced by real fires

Goal: Use computational tools to analyze steel joist behavior under fire
Experimental Testing

- Experimental tests conducted on a frame flooring system
- Flooring consisted of 4 joists, 2 tracks, plasterboard, and plywood
- Target load of 9 kN was applied to each joist
- A furnace created fire conditions based on standard fire curve
- Temperature, lateral deflection, and failure time were recorded
Experimental Results
Abaqus Model Criteria

- **Joist Dimensions**: 180 x 40 x 15 x 1.15 mm
- **Material Properties**:  
  - Modeled as changing due to temperature except Poisson’s Ratio which remains constant
- **Boundary Conditions**:  
  - Model based on connections to plasterboard and plywood
- **Load**: 9 kN was uniformly distributed
- **Temperature**: Modeled after experimental results
Model Results

- The Abaqus Steel Joist Model produces results that are similar to the results produced from the experimental testing.
- The error between the experimental and model results was calculated to be 5% or less.

### Failure Results

<table>
<thead>
<tr>
<th>Type</th>
<th>Experimental Results</th>
<th>Model Results</th>
<th>%Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (minutes)</td>
<td>107</td>
<td>107.697</td>
<td>1%</td>
</tr>
<tr>
<td>Temperature</td>
<td>450, 400, 340</td>
<td>459.233</td>
<td>2%</td>
</tr>
<tr>
<td>Lateral Deflection (in)</td>
<td>0.967041516</td>
<td>1.01128</td>
<td>5%</td>
</tr>
<tr>
<td>Slope of Deflection</td>
<td>0.014629383</td>
<td>0.014704056</td>
<td>1%</td>
</tr>
</tbody>
</table>
Parametric Study

- Goal: To observe how each parameter affects the model and the results
- Conducted six parametric studies

Main Parameters:
- Material Properties - Poisson’s Ratio and Thermal Expansion Coefficient
  - Compare results with constant and varying values
- Changing the length of joist
## Parametric Study Results

### Material Properties Study

<table>
<thead>
<tr>
<th>Type</th>
<th>Abaqus Model Results</th>
<th>Poisson's Ratio Results</th>
<th>% Difference</th>
<th>Thermal Expansion Coefficient</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (minutes)</td>
<td>107.697</td>
<td>107.709</td>
<td>0%</td>
<td>108</td>
<td>0%</td>
</tr>
<tr>
<td>Temperature</td>
<td>459.233</td>
<td>459.367</td>
<td>0%</td>
<td>462.624</td>
<td>1%</td>
</tr>
<tr>
<td>Lateral Deflection (in)</td>
<td>1.01128</td>
<td>1.06816</td>
<td>5%</td>
<td>0.888062</td>
<td>13%</td>
</tr>
<tr>
<td>Stress</td>
<td>88.6983</td>
<td>87.9985</td>
<td>1%</td>
<td>86.7214</td>
<td>2%</td>
</tr>
</tbody>
</table>

### Length Study

<table>
<thead>
<tr>
<th>Type</th>
<th>Original Length 2400mm</th>
<th>Length 1500mm</th>
<th>Length 1000mm</th>
<th>Length 500mm</th>
<th>Length 3000mm</th>
<th>Length 3500mm</th>
<th>Length 4000mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (minutes)</td>
<td>107.697</td>
<td>108</td>
<td>108</td>
<td>108</td>
<td>87.0036</td>
<td>83.0564</td>
<td>77.1088</td>
</tr>
<tr>
<td>Temperature</td>
<td>459.233</td>
<td>462.624</td>
<td>462.624</td>
<td>462.624</td>
<td>326.797</td>
<td>296.813</td>
<td>263.327</td>
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<td>Lateral Deflection (in)</td>
<td>1.01128</td>
<td>0.843906</td>
<td>0.585979</td>
<td>0.486279</td>
<td>0.88673</td>
<td>0.882696</td>
<td>0.838699</td>
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<tr>
<td>Stress</td>
<td>88.6983</td>
<td>86.31</td>
<td>71.79</td>
<td>65.6676</td>
<td>100.15</td>
<td>100.291</td>
<td>100.137</td>
</tr>
</tbody>
</table>
Experimental vs. Computational Study:
- Abaqus can accurately model steel joists under fire conditions
  - Prevents spending money for experimental testing
  - More joist configurations can be tested
  - Provides an easier method to model steel joists under fire

Parametric Study:
- Thermal Expansion Coefficient must vary with temperature to provide accurate results
- The length of the joist effects how and when it fails under fire
References


